

# Corrosion Preventing Characteristics of Military Hydraulic Fluids Part II

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## ABSTRACT

Hydraulic systems are widely used in a variety of military applications including ground vehicles, aircraft, and weapon systems. The impact of corrosion on hydraulic systems and its components is well understood; however, the protection provided by different hydraulic fluids is not equal<sup>1</sup>. Review of military vehicle hydraulic systems has identified that the most common occurrences of critical corrosion are found in hoses, hose end fittings, actuator arms, pistons, cylinders, and rams<sup>1</sup>. To prevent corrosion in hydraulic systems, the U.S. Army has specified the use of hydraulic fluids with corrosion preventing and rust inhibiting characteristics for ground vehicles.

Currently, the Army uses three different types of fluids in the hydraulic systems of military ground vehicles and equipment; MIL-PRF-46170, MIL-PRF-6083, and MIL-PRF-2104. To verify the corrosion protection performance of the fluids, the Fuels and Lubricants Technology Team (FLT) of U.S. Army Tank Automotive Research Development and Engineering Center (TARDEC) continued an investigation to compare the corrosion preventing characteristics of military hydraulic fluids and engine oils based on standardized hydraulic fluid corrosion tests found in the hydraulic fluid specifications. The test results continue to show that MIL-PRF-6083 and MIL-PRF-46170 provide better corrosion protection than other non-rust inhibiting military hydraulic fluids<sup>2-3</sup>. This follow-up report will provide updated test results demonstrating improved corrosion protection can be achieved for Army ground vehicle systems.

## INTRODUCTION

Military hydraulic fluids are required to provide a specific level of corrosion protection based on the system design and operational environment. Military ground vehicle hydraulic systems have been shown to corrode and rust when using non-rust inhibited hydraulic fluids. Hydraulic fluids formulated with a rust inhibitor have shown effectiveness at reducing corrosion and rust in these systems. As a result, the Army has adopted the use of rust inhibited hydraulic fluids for ground vehicle

applications. Although these rust inhibited fluids have been shown to provide additional corrosion and rust protection, they are prohibited from use in aviation equipment. Reports published by the Air Force state the rust inhibited fluids are not thermally stable above 121°C and therefore cause sticking of critical servo and poppet valves<sup>4</sup>. The objective of this follow-up study is to quantify the level of corrosion protection provided by all applicable military hydraulic fluids and engine oils, to better understand their capabilities, and operational limitations.

Part one of this publication discussed corrosion, its definition and effect on military hydraulic systems. Corrosion is defined as the deterioration of a metallic surface by chemical or electrochemical action<sup>5</sup>. In order to have an electrochemical event, there must be an anode, a cathode and a conductive fluid or electrolyte. The anode and cathode can be two dissimilar metals in contact, such as in galvanic corrosion, or it can be different "phases" within one alloy, or a varying of concentrations of electrolyte on a metal<sup>6</sup>. Several types of corrosion were investigated in a series of experiments including galvanic from dissimilar metals, crevice and pitting, resulting from concentration differentials, and intergranular attack between grains of alloys<sup>6</sup>.

The military hydraulic fluids and engine oils were evaluated using four classifications of corrosion testing summarized in Table 1<sup>7</sup>.

Table 1: Category of Laboratory Corrosion Tests

Category	Test	ASTM Method Number
Immersion	Rust Preventing Procedure A & B Copper Corrosion	D 665 D 130
Simulated Atmosphere	Humidity Cabinet Corrosiveness and Oxidation Stability	D 1748 D 4636
Electrochemical	Galvanic Corrosion	D 6547
Environmentally Aggressive	Rust Preventing Procedure B	D 665

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The Army, in order to prevent corrosion, has specified corrosion requirements, which necessitates the use of corrosion and rust inhibitors in hydraulic fluids. The most common rust inhibitor used today is barium dinonyl naphthalene sulfonate (BDNS). The corrosion/rust inhibitors used in the engine oils are not available because of inclusion in the oil's proprietary additive package<sup>5</sup>.

Presently, the Army's hydraulic systems employ two different hydraulic fluids and, in some cases, also engine oil. MIL-PRF-46170 is the Army's rust inhibited; fire resistant, synthetic hydrocarbon based hydraulic fluid intended for use in recoil mechanisms and hydraulic systems of military ground vehicles and equipment. Secondly, MIL-PRF-6083 is the Army's rust inhibited petroleum based hydraulic fluid used for preservation and operation. Finally, MIL-PRF-2104 is the Army's multipurpose lubricating oil for internal combustion engines used in combat and tactical service. In a project performed by FLTT to determine the uses of MIL-PRF-2104 in other than crankcase applications, it was discovered that approximately 40% of the systems researched recommend MIL-PRF-2104 as the vehicles hydraulic fluid<sup>8</sup>. Using standardized corrosion tests, FLTT compared the corrosion and rust inhibiting properties of 10 military hydraulic fluids and engine oils. Since the use of rust inhibiting additives is not promoted across Department of Defense (DOD), it is important to determine which fluids will protect the Army's equipment from corrosion and rust.

## LABORATORY INVESTIGATION

### SAMPLE IDENTIFICATION

Five military hydraulic fluids and five engine oils of varying types and grades were chosen to be included in this evaluation:

#### Hydraulic Fluids

- MIL-PRF-5606 – Hydraulic Fluid, Petroleum Base; Aircraft, Missile, and Ordnance (Air Force)<sup>9</sup>
- MIL-PRF-6083 – Hydraulic Fluid, Petroleum Base, for Preservation and Operation (Army)<sup>2</sup>
- MIL-PRF-46170 – Hydraulic Fluid, Rust Inhibited, Fire Resistant, Synthetic Hydrocarbon Base (Army)<sup>3</sup>
- MIL-PRF-83282 – Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base (Navy)<sup>10</sup>
- MIL-PRF-87257 – Hydraulic Fluid, Fire Resistant; Low Temperature, Synthetic Hydrocarbon Base, Aircraft and Missile (Air Force)<sup>11</sup>

#### Engine Oils

- MIL-PRF-2104 – Lubricating Oil, Internal Combustion Engine, Combat/Tactical Service (10W and 15W40)<sup>12</sup>
- MIL-PRF-21260 – Lubricating Oil, Internal Combustion Engine, Preservative Break-In (10W and 15W40)<sup>13</sup>
- MIL-PRF-46167 – Lubricating Oil, Internal Combustion Engine, Artic (0W30)<sup>14</sup>

## CORROSION TESTING PARAMETERS

This publication is a follow-up to the paper entitled, "Corrosion Preventing Characteristics of Military Hydraulic Fluids Part I." In addition to the three corrosion tests from Part 1, three additional corrosion tests were performed on the selected hydraulic fluid and engine oils samples per American Society for Testing and Materials (ASTM) methods. The three corrosion tests include Rust Preventing Characteristics of Inhibited Oil (ASTM D 665)<sup>15</sup>, Corrosiveness to Copper from Petroleum Products by Copper Strip Test (ASTM D 130)<sup>16</sup>, and Corrosiveness and Oxidation Stability of Hydraulic Oils (ASTM D 4636)<sup>17</sup>. While the three tests evaluate the corrosion preventing characteristics of the respective fluids, each test offers a different corrosive environment.

### Rust-Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water (ASTM D 665)

This test method evaluates the ability of the sample fluid to prevent rust from forming on ferrous materials if and when the sample fluid comes in contact with sea salt water. Two steel test rods were prepared according to ASTM D 665 for each fluid. Procedure B is chosen to test the oil using synthetic sea water. Explanation on why the sea water test was selected is provided under Discussions.

Table 2 compares the results from the rust-preventing characteristics of inhibited mineral oils in the presence of distilled water (previously tested in part I) and sea salt water. A failure is a test rod that contains any rust spot or rust streak observed without magnification.

Table 2: Rust-preventing characteristics of inhibited oils in the presence of distilled water and synthetic sea water results.

	Sample	Distilled Water	Sea Water
Internal Combustion Engine Oils	MIL-PRF-21260 15W40	Pass	Pass
	MIL-PRF-21260 10W	Pass	Pass
	MIL-PRF-46167	Pass	Pass
	MIL-PRF-2104 15W40	Pass	Pass
	MIL-PRF-2104 10W	Pass	Pass
Army Hydraulic Fluids	MIL-PRF-46170	Pass	Pass
	MIL-PRF-6083	Pass	Pass
Air Force Hydraulic Fluids	MIL-PRF-87257	Pass	Fail
	MIL-PRF-5606	Pass	Fail
Navy Hydraulic Fluid	MIL-PRF-83282	Pass	Fail

The following figures are examples of the amount of corrosion that is likely to occur in hydraulic systems which operate in salt water conditions.

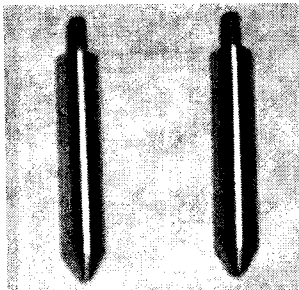


Figure 1: MIL-PRF-46170

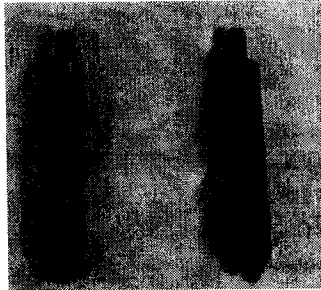


Figure 2: MIL-PRF-87257

Figure 1 displays a passing test in which no corrosion occurs after 4 hours in a salt water atmosphere. In contrast, Figure 2 displays the corrosive attack for MIL-PRF-87257 after 4 hours in a sea salt water environment. The test resulted in a very severe corrosion noted by rust and pitting of the metal. Formation of pits is often observed in electrolytes with chloride (Cl<sup>-</sup>) ions present, such as salt water. The ions will break down the protective passive oxide film allowing small pits to develop on the exposed surface. This is a form of a localized concentration cell attack<sup>6</sup>.

The test data indicate there is an increased risk of corrosive attack on the system relative to the corrosion/rust protection provided by the fluid. The aviation hydraulic fluids will not protect against rust in sea water circumstances. Comparing the sea water to the distilled water results indicates added corrosion protection is required in harsher environments.

#### Corrosiveness to Copper from Petroleum Products by Copper Strip Test (ASTM D 130)

This test method evaluates the ability of the sample fluid to prevent corrosion on copper material. Two copper strips are prepared according to ASTM D 130 for each fluid. Table 3 shows the results from the copper strip corrosion test by means of this grading system.

Failure to this test is based on requirements specified by MIL-PRF-6083, which is a maximum color change of classification 3a. MIL-PRF-46170, currently, does not have a requirement specified for the Copper Strip Test.

Table 3: Corrosiveness to Copper by the Copper Strip Test

	Sample	Strip 1	Strip 2	pass/fail
Engine Oils	MIL-PRF-21260 15W40	4b	4b	Fail
	MIL-PRF-21260 10W	4b	4b	Fail
	MIL-PRF-46167	1b	1b	Pass
	MIL-PRF-2104 15W40	1b	1b	Pass
	MIL-PRF-2104 10W	2c	3a	Pass
Army Hydraulic Fluid	MIL-PRF-46170	1b	1b	Pass
	MIL-PRF-6083	1a	1a	Pass
Air Force Hydraulic Fluid	MIL-PRF-87257	1b	1b	Pass
	MIL-PRF-5606	1a	1a	Pass
Navy HF	MIL-PRF-83282	1b	1b	Pass

The following figures exemplify the corrosion or lack of corrosion in a specific fluid held at 100°C for 72 hours. This shows the types of corrosion to be expected on copper metals of hydraulic systems under field conditions.



Figure 3: MIL-PRF-46170

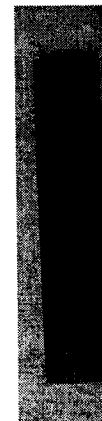


Figure 4: MIL-PRF-21260

Figure 3 shows a passing test in which no corrosion forms in the 72 hours at the specified temperature. However, a slight tarnish is seen and noted as classification 1b resulting in a dark orange color. In comparison, Figure 4 shows corrosion classified as a 4b because of its black color. Classification of these copper strips is not only by the chart given in ASTM D 130 but also performed via a side-by-side comparison to the given ASTM Copper Corrosion Standards.

The preservative oil engine oil, MIL-PRF-21260 did not meet copper strip corrosion requirements needed for the

Army ground vehicles hydraulic systems. Aviation hydraulic fluids meet expectations and pass this test.

Corrosiveness and Oxidation Stability of Hydraulic Oils, Aircraft Turbine Lubricants, and Other Highly Refined Oils (ASTM D 4636)

This test examines the sample fluids oxidation and corrosive degradation as well as the interaction with various metals. These metals include: aluminum, cadmium, copper, magnesium, and steel. This test imitates what the lubricant experiences in its working environment. By using high temperature and air agitation, the test is accelerated to allow measurable results in a sensible amount of time. The metals used in the test provide catalytic reactive surfaces of materials that are commonly found in real systems<sup>17</sup>.

An oxidation reaction occurs at the anode in a corrosion cell. At the anode, ions leave the metal and enter the electrolyte while the electrons released during ionization leave the anode through an electrical connection and travel to the cathode where they are used in one or more reduction reactions. This results in corrosion and often pitting<sup>6</sup>.

The test is run for 7 days at temperatures of 121°C (per Army requirements) and 135°C (per Air Force requirements) with an air flow of 5 L/hr. Five metals are arranged and tied together using tantalum wire as seen in Figure 5. The arrangement is then placed in the sample fluid and into the sample tubes and into an aluminum block heater at specified temperatures. At the end of the test, the apparatus is taken apart and both the fluid and the metal specimens are evaluated. The fluid is evaluated by running total acid number and kinematic viscosity. The metal specimens are examined for corrosion and weight gain or loss. Table 5 displays the test results for the overall tests (individual data for each fluid is included in Appendix A and B).

Failure to this test is based on requirements specified by MIL-PRF-46170 when run at 121°C and MIL-PRF-87257 when run at 135 °C. See Table 4 for the requirement comparison.

Table 4: Requirements per specifications.

MIL-PRF-		46170	6083	87257	5606	83282
Temperature		121°C			135°C	
Properties		Test Limits				
Metal Specimen Wt	Aluminum	0.2 mg/cm <sup>2</sup>				
	Cadmium	0.2 mg/cm <sup>3</sup>				
	Copper	0.6 mg/cm <sup>2</sup>				
Change (max)	M-50 Steel	0.2 mg/cm <sup>3</sup>				
	Magnesium	0.2 mg/cm <sup>3</sup>				
Percent Change in Viscosity		±10%	-5% to +20%	±10%	-5% to +20%	±10%
Change in Acid Number (max)		0.3 mg KOH/g	0.2 mg KOH/g			
Sediment		None				

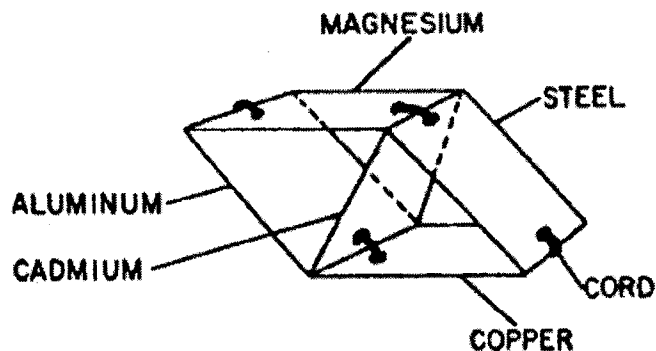


Figure 5: Arrangement of metal test specimens<sup>17</sup>.

Table 5: Results of ASTM D 4636

	Sample	At 121°C	At 135°C
Engine Oils	MIL-PRF-21260 15W40	Fail	Fail
	MIL-PRF-21260 10W	Fail	Fail
	MIL-PRF-46167	Pass	Fail
	MIL-PRF-2104 15W40	Pass	Pass
	MIL-PRF-2104 10W	Pass	Fail
Army Hydraulic Fluids	MIL-PRF-46170	Pass	Fail
	MIL-PRF-6083	Pass	Fail
Air Force Hydraulic Fluids	MIL-PRF-87257	Pass	Pass
	MIL-PRF-5606	Pass	Pass
Navy Hydraulic Fluid	MIL-PRF-83282	Pass	Pass

\*\*Detailed test data can be found in Appendix A.

The following pictures show the corrosive attack on the metal specimens when subjected to high heat in an oxygenated atmosphere. Specifically, the pictures show the effects on copper and cadmium. Aluminum, steel, and magnesium showed minimal to no change in metal before and after observations. For comparison reasons, a picture of the freshly polished specimen is also included.

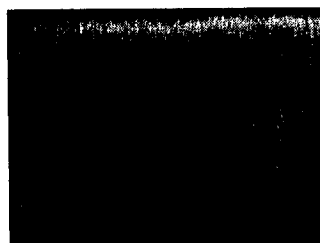


Figure 6: Freshly Polished Copper

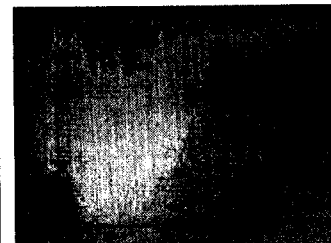


Figure 7: MIL-PRF-21260 15W40 (Copper - 3b corrosion at 135°C)

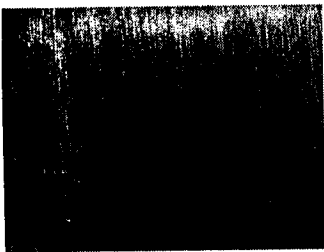


Figure 8: Freshly Polished Cadmium

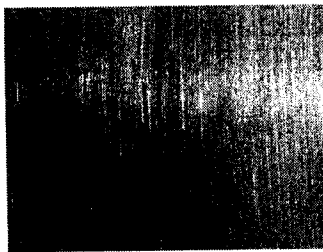


Figure 9: MIL-PRF-2104 10W (Cadmium - tan colored at 135°C)

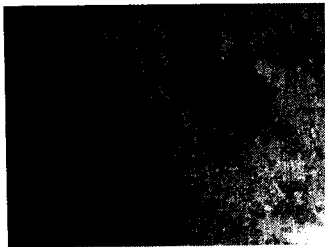


Figure 10: MIL-PRF-6083 (Cadmium - corrosion at 135°C)

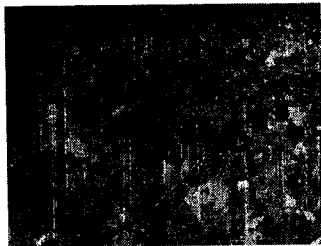


Figure 11: MIL-PRF-46170 (Cadmium - corrosion at 135°C)

ASTM D 4636 looks in depth at the corrosion effects on five metals. Steel, magnesium, and aluminum are all commonly found in engine components. Copper has been recently added in aluminum wear-resistant alloys because of its ability to provide additional strength through processes such as aging and precipitation-hardening. However, as copper is added, some corrosion resistance benefits are negatively effected<sup>18</sup>.

In examination of this test, it is also necessary to observe the change in properties of the fluid, such as change in total acid number (TAN) and viscosity, as well as noting the change in color and sludge formation. In observing the test outcome, it has become clear that engine oils and hydraulic fluids react proportionally to the level of protection provided by their additive package. The additive package can further influence property behavior indirectly. For instance, engine oils with viscosity modifying additives decompose at higher operating temperatures creating a greater change in viscosity after the test.

When analyzing the degradation of an oil or hydraulic fluid, the increase in total acid number (TAN) is one indicator of its degradation. However, upon reviewing the data acquired during the oxidation and stability test, the TAN of the engine oils were decreasing, while the acid numbers of the hydraulic fluids were constant or slightly increasing. Therefore, the test generated minimal oxidation by-products in the hydraulic fluids. However, the phenomenon experienced in the engine oils may be attributed to the engine oil formulations. Internal combustion engine oils are formulated with a base number (TBN) to combat acid formation during the combustion process.

In order to explain the decrease in TAN for the engine oils, the total base number (TBN) of two of the engine oil

samples was evaluated before and after the corrosion and oxidation stability test at 121°C and 135°C. The evaluation indicated a net decrease in TBN for the samples. Additionally, at the higher test temperature (135°C), a greater net decrease in both base and acid numbers was observed.

## DISCUSSION

This investigation was conducted to determine the suitability of available military hydraulic fluids to meet a wide range of military-unique operational environments. Military ground equipment and aviation equipment encounter different operating environments. Military hydraulic systems are designed to operate in both high and low humidity and temperature extremes.

Military hydraulic systems may also encounter salt water conditions; similar to environments on a pre-positioned ship or locations near coastal areas. Corrosion and rust protection against salt water has not been previously addressed, as specification requirements do not exist. In order to determine how the products protect equipment operating in salt environments, the rust preventing characteristics (pin rust) test, procedure B was completed. Test results indicate the corrosion/rust inhibitors in MIL-PRF-6083 and MIL-PRF-46170 provide protection against salt water corrosion. Future revisions of Army specifications may include this test to ensure any future fluid development and/or additive improvements do not adversely impact this important property.

Ground vehicle hydraulic fluids are required to meet the lower temperature (121°C) for corrosion and oxidation protection; aviation hydraulic fluids are required to perform at 135°C. However, as future equipment is developed, hydraulic fluids will be expected to perform at higher pressures and operating temperatures. The current corrosion/rust inhibitor in the Army's ground vehicle fluids fail to provide protection at the higher temperature (135°C) and research is necessary to ensure these fluids can meet future needs.

The major difference between the ground vehicle and aviation hydraulic fluids is the corrosion/rust inhibitor formulated into the Army's ground vehicle fluids. Based on the data gathered in this study, the corrosion/rust inhibitor is necessary to protect the hydraulic systems from corrosion in both the humidity and salt water conditions encountered by the Army.

Appendix A, Table A-3 summarizes the results from Part I and those presented in this paper. Overall, MIL-PRF-46170 and MIL-PRF-6083 provided the level of protection needed for Army equipment, but this work also identified additional areas that need improvement.

In the future, the Army will seek to develop a synthetic, fire resistant hydraulic fluid formulated with a corrosion/rust inhibitor that is thermally stable at elevated temperatures. Thus, the hydraulic fluid will protect the

hydraulic system from corrosion and rust in high temperature conditions as well as maintain or exceed the current level of corrosion/rust protection.

## CONCLUSION

Hydraulic systems require a fluid to provide a level of corrosion, rust, and oxidation protection relative to their operating conditions. Military ground vehicles, operating in high humidity, a salt environment, or a moisture retaining mud, grease, or debris conditions, require increased corrosion and rust protection; aviation hydraulic fluids require a high level of thermal stability. These performance requirements are captured in their respective specifications.

Corrosion and rust inhibiting additive technology has been demonstrated to significantly improve the corrosion and rust protection provided by hydraulic fluids over those not formulated with a rust inhibitor. These results are most evident as the evaluation environment is made more demanding. When increasing rust and corrosion test condition severity, a clear dichotomy is observed between corrosion/rust inhibited hydraulic fluids and hydraulic fluids that do not have a rust inhibitor. For instance, when transitioning from a distilled water medium to salt water, fluids formulated without a rust inhibitor, meeting Navy and Air Force military hydraulic fluid specifications, failed to provide the same level rust protection to ferrous metals in each medium. In contrast, the rust inhibited ground vehicle hydraulic fluids and engine oils were capable of providing the increased protection.

Similarly, corrosiveness and oxidation stability test conditions were made more demanding to evaluate the capability of the fluid under more stringent criteria. The ground vehicle hydraulic fluids and engine oils were unable to provide a satisfactory level of protection at 135°C. As expected, the aviation hydraulic fluids met this requirement. As indicated before, future Army equipment is expected to require hydraulic fluids with higher thermal stability. Therefore, future research and development is required.

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# APPENDIX A

Table A-1: Data from 121°C

AT TEMPERATURE 121 deg C			Metal Appearance											
Specification	Viscosity Change (%)	Δ Acid Number (mg KOH/g)	Oil Appearance	Sediment Weight	Aluminum (mg/cm2)		Cadmium (mg/cm2)		Copper (mg/cm2)		Magnesium (mg/cm2)		Steel (mg/cm2)	
MIL-PRF-21260 15W40	-5.3	-0.97	Dark Brown	0	0	shiny	0	A	-2	4a	0	tan	0	A
MIL-PRF-21260 10W	-0.864	-0.62	Dark Brown	0	0	shiny	0	A	-2	4b	0	tan	0	A
MIL-PRF-46167	-2.5	-0.33	Dark Red	0	0	shiny	0	tan	-0.1	1b	0	A	0	A
MIL-PRF-46170	0.864	0.20	Brown	0	0	shiny	0	A	0	2b	0	A	0	A
MIL-PRF-6083	1.034	0.04	Brown	0	0	shiny	0	tan	0	1b	0	A	0	A
MIL-PRF-87257	0.931	-0.03	Red	0	0	shiny	0	tan	0	2b	0	bluish tan	0	A
MIL-PRF-83282	-0.207	-0.06	Red	0	0	shiny	0	tan	0	2b	0	A	0	A
MIL-PRF-2104 15W40	2.257	-0.06	Brown	0	0	shiny	0	tan	0	1a	0	A	0	A
MIL-PRF-5606	3.274	0.02	Red	0	0	shiny	0	tan	0	1b	0	A	0	A
Mil-PRF-2104 10W	-3.047	-0.20	Brown	0	0	shiny	0	A	0	1a	0	tan	0	A
**A = Acceptable														
Specification	Viscosity Change (%)	Δ Acid Number (mg KOH/g)	Oil Appearance	Sediment Weight	Aluminum (mg/cm2)		Cadmium (mg/cm2)		Copper (mg/cm2)		Magnesium (mg/cm2)		Steel (mg/cm2)	
MIL-PRF-21260 15W40	Pass	Pass	A	Pass	pass		pass		Fail		pass		pass	
MIL-PRF-21260 10W	Pass	Pass	A	Pass	pass		pass		Fail		pass		pass	
MIL-PRF-46167	Pass	Pass	A	Pass	pass		pass		Pass		pass		pass	
MIL-PRF-46170	Pass	Pass	A	Pass	pass		pass		pass		pass		pass	
MIL-PRF-6083	Pass	Pass	A	Pass	pass		pass		pass		pass		pass	
MIL-PRF-87257	Pass	Pass	A	Pass	pass		pass		pass		pass		pass	
MIL-PRF-83282	Pass	Pass	A	Pass	pass		pass		pass		pass		pass	
MIL-PRF-2104 15W40	Pass	Pass	A	Pass	pass		pass		pass		pass		pass	
MIL-PRF-5606	Pass	Pass	A	Pass	pass		pass		pass		pass		pass	
Mil-PRF-2104 10W	Pass	Pass	A	Pass	pass		pass		pass		pass		pass	

Table A-2: Data from 135°C

AT TEMPERATURE 135 deg C			Metal Appearance											
Specification	Viscosity Change (%)	Δ Acid Number (mg KOH/g)	Oil Appearance	Sediment Weight	Aluminum (mg/cm2)		Cadmium (mg/cm2)		Copper (mg/cm2)		Magnesium (mg/cm2)		Steel (mg/cm2)	
MIL-PRF-21260 15W40	-6.65	-0.90	Dk Brown	0	0	A	0	tan	-1.6	3b	0	tan	0	tan
MIL-PRF-21260 10W	-6.44	-0.95	Dk Brown	0	0	A	0	tan	-7.36	2c	0	tan	0	tan
MIL-PRF-46167	-2.83	-0.20	Dk Brown	0	0	A	0	tan	0	4a	0	tan	0	tan
MIL-PRF-46170	0.928	0.71	Dk Brown	0	0	A	-13.8	pitting	0	2a	0	A	0	tan
MIL-PRF-6083	3.288	0.80	Dk Brown	0	0	A	-4.5	redish	-1.7	2c	0	A	0	tan
MIL-PRF-87257	1.039	0.04	Red	0	0	A	0	tan	0	3a	0	A	0	tan
MIL-PRF-83282	0.138	-0.03	Red	0	0	A	0	tan	0	1b	0	A	0	A
MIL-PRF-2104 15W40	3.602	-0.34	Dk Brown	0	0	A	0	A	0	2c	0	A	0	A
MIL-PRF-5606	3.679	0.08	Dk Brown	0	0	A	0	tan	0	1b	0	A	0	A
Mil-PRF-2104 10W	-7.13	0.61	Dk Brown	0	0	A	0	tan	0	4a	0	tan	0	tan
**A = Acceptable														
At Temp 135	Viscosity Change (%)	Δ Acid Number (mg KOH/g)	Oil Appearance	Sediment Weight	Aluminum (mg/cm2)		Cadmium (mg/cm2)		Copper (mg/cm2)		Magnesium (mg/cm2)		Steel (mg/cm2)	
MIL-PRF-21260 15W40	Pass	Pass	A	pass	Pass		Pass		Fail		Pass		Pass	
MIL-PRF-21260 10W	Pass	Pass	A	pass	Pass		Pass		Fail		Pass		Pass	
MIL-PRF-46167	Pass	Pass	A	pass	Pass		Pass		Fail		Pass		Pass	
MIL-PRF-46170	Pass	Fail	A	pass	Pass		Fail		Pass		Pass		Pass	
MIL-PRF-6083	Pass	Fail	A	pass	Pass		Fail		Fail		Pass		Pass	
MIL-PRF-87257	Pass	Pass	A	pass	Pass		Pass		Pass		Pass		Pass	
MIL-PRF-83282	Pass	Pass	A	pass	Pass		Pass		Pass		Pass		Pass	
MIL-PRF-2104 15W40	Pass	Pass	A	pass	Pass		Pass		Pass		Pass		Pass	
MIL-PRF-5606	Pass	Pass	A	pass	Pass		Pass		Pass		Pass		Pass	
Mil-PRF-2104 10W	Pass	Fail	A	pass	Pass		Pass		Fail		Pass		Pass	

Table A-3: Summary of Data for Part I and Part II

	Corrosiveness & Oxidation @ 121°C	Corrosiveness & Oxidation @ 135°C	Galvanic Corrosion	Rust Preventing Procedure A	Rust Preventing Procedure B	Copper Corrosion	Humidity Cabinet
ASTM Method	D4636	D4636	D6547	D665	D665	D130	D1748
MIL-PRF-21260 15W40	Fail	Fail	Pass	Pass	Pass	Fail	Pass
MIL-PRF-21260 10W	Fail	Fail	Pass	Pass	Pass	Fail	Pass
MIL-PRF-46167	Pass	Fail	Pass	XXXX	Pass	Pass	Pass
MIL-PRF-2104 15W40	Pass	Pass	Pass	Pass	Pass	Pass	Fail
MIL-PRF-2104 10W	Pass	Fail	Pass	Pass	Pass	Fail	Fail
MIL-PRF-46170	Pass	Fail	Pass	Pass	Pass	Pass	Pass
MIL-PRF-6083	Pass	Fail	Pass	Pass	Pass	Pass	Pass
MIL-PRF-87257	Pass	Pass	Pass	Pass	Fail	Pass	Fail
MIL-PRF-5606	Pass	Pass	Pass	Pass	Fail	Pass	Fail
MIL-PRF-83282	Pass	Pass	Pass	Pass	Fail	Pass	Fail

XXXX – Test was not run